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ON THE CHOICE AND USE

OF

PHOTOGRAPHIC LENSES,

BY

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PREFACE.

In issuing this Edition of my late Father's Pamphlet, "On the Choice and Use of Photographic Lenses," I have retained the original matter as it stood, with its references to work done by well-known artists, although some of them are now deceased.

I have included several papers that he contributed to Photographic Journals, bearing directly upon the use of the Lens and Camera; and added a short explanation of the Law of Conjugate Foci, together with several Tables (for enlargement and reduction, intensity ratios, relative exposures, &c.), with a view of answering many questions that arise almost daily.

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PORTRAIT LENSES.

SUCCESS IN PORTRAITURE will always depend, in a great measure, upon the *right choice and proper use* of the lens. A few hints on these two points may prove of service to the photographer.

Portrait lenses are either more or less rapid in action, as their diameters are larger or smaller, or as their focal lengths are shorter or longer. The diameter of a lens here always implies the *actual* working aperture, and the focal length, its *equivalent* focal length. Directions for ascertaining these are given in the Appendix.

The focal length of a lens determines the *size* of the picture, and the diameter, or aperture, its speed or *rapidity* of action. Having fixed upon the size of picture required to be taken, the next thing to be determined is the most suitable focal length of the lens. This, however, involves the prior determination of the *distance* at which to place the subject; for every photographer knows that by bringing the lens nearer the subject, he increases the size of the picture; and *vice versâ.* The question then arises: "What is the proper distance at which to place the subject from the lens?" In answer it may be safely asserted, that it should not, as a rule, be less than 12 feet, nor perhaps more than 24 feet. For if less than this, the resulting picture will generally be defective both in definition and perspective, because the lens producing it will be of too short a focus. If the distance is greater, the resulting picture will probably be deficient in relief or roundness, because the atmosphere in our towns is seldom quite free from fog or haze, and the greater the distance between the lens and subject, the more obviously will this haze be reproduced in the picture.

A medium distance, therefore, of from 15 to 20 feet should be chosen. Card portraits are generally taken with lenses of such focal lengths as to require this distance, and to this circumstance may be attributed the generally pleasing appearance of these portraits as compared with the old quarter plate pictures, which were mostly taken with lenses of much shorter focal lengths.

For a distance, then, of from 15 to 20 feet between the lens and subject, the *equivalent* focal length (not the back focus) of the lens, for a given sized plate, should be about *twice* that of the largest size; that is, for a $4\frac{1}{4} \times 3\frac{1}{4}$ plate, the card size, the focal length should be $4\frac{1}{4} \times 2$, or equal to $8\frac{1}{2}$ inches, *i.e.*, No. 2 B lens; for a 6×5 plate, the cabinet size, 6×2, equal to 12 inches, *i.e.*, 3 B, 2 A, or, better still, 3 A lens; for a 10×8 plate, 10×2, equal to 20 inches, *i.e.*, 4 A lens; and so on.

In confirmation of this, I may mention that the much admired 10×8 pictures of the late M. Adam-Salomon were taken with a 20-inch focal length lens.

The distance between the lens and subject here given require a studio of at least 30 feet in length; and photographers who have not this space are compelled to use lenses of shorter foci, such as the 1 B [long] or 1 B for cards, and the 1 A for cabinets; but they labour under disadvantages as regards instrumental aid, which no amount of skill can possibly compensate.

Having determined the *focal length* of the lens for a given-sized plate, the next thing requiring consideration is its *diameter*, or its rapidity of action. As a matter of course, every photographer wishes to possess a quick-acting lens, and not only this, but flatness of field, and great "depth" of focus or definition, forgetting all the while that these qualities are almost diametrically opposed; for rapidity can only be had at a corresponding sacrifice of flatness of field and depth of definition. Thus, of two lenses of the same focal length, and both perfectly corrected for spherical aberration, the one of 2 inches in diameter will have twice the depth of another of 4 inches in diameter; whilst the latter, in turn, is four times quicker in action than the former.

Again, of two lenses of the same rapidity (*i.e.*, having the same ratio of aperture to focal length) the one double the focal length of the other, will only have one quarter its "depth." Thus, for example, a card lens of 9 inches focal length, and $2\frac{3}{4}$ in aperture, producing a card picture at 20 feet distance, will sufficiently define accessories 12 inches in front and 12 inches behind the figure, or the point focussed upon, or will have a depth of 2 feet; whereas, another lens of double the above dimensions, *i.e.*, of 18 in. focus and $5\frac{1}{2}$ inches aperture, and worked at the *same distance*, will only have a depth of 6 inches, viz., 3 inches before and 3 inches behind the point focussed upon. This sufficiently explains that quick-acting lenses only produce satisfactory results when used for the smaller-sized plates; but that they are useful, when so restricted, is sufficiently evidenced by the charming instantaneous portraits of children by Mr. Faulkner, Mr. H. C. Heath, and others, taken with Nos. 2 C and 3 C—perhaps the quickest acting lenses extant.

For standing figures these lenses require stopping down, as explained in my Catalogue.

Hence, the quick acting, or B lenses, are only constructed for plates up to $8\frac{1}{2} \times 6\frac{1}{2}$. For larger pictures, slower working lenses capable of adjustment for diffusion of focus, are the only means for securing the requisite amount of depth of focus.

It may be stated here that for every-day work, for whole-plate portraits, and larger sizes, the patent A lenses are the most suitable. They are nearly twice as rapid in action as the D lenses, of great importance considered from a commercial point of view, for long exposures very often occasion a failure. Hence nearly all the first artists, as for instance, Messrs. Blanchard, Bourne & Sheppard, Bergamosco, Heath, Hughes, Hanfstangl, Lock and Whitfield, Abel Lewis, Levitsky, Mayland, Robinson, Slingsby, Hugo Thiele, Wane, and others, constantly use these lenses for the ordinary demand of portraits; but for their extra large-size pictures, the first-named artist uses No. 5 or 6 D, Mr. Slingsby a No. 7 D, and the late Mr. Crawshay, for the largest portraits, perhaps, ever taken direct, used a No. 8 D. Excellent large portrait studies have also been

taken with the rapid rectilinear lenses by the late Mrs. Cameron and others.

Thus much respecting the right choice of the lens; and now a few words regarding the proper use of it.

The lens, when attached to the camera, should be placed upon a *firm* stand, capable of adjustment as to height, &c.; the cap should fit the lens loosely, so that its removal does not cause tremor or shaking of the camera. Cap the lens, and, protected by the focussing cloth, carefully examine the interior of the camera to insure a perfect dark chamber. No bright object such as the unblackened head of a screw, or a bright brass spring on the shutter, should be tolerated anywhere. The wood of the interior of the camera, should be coated with a *dead*, and not a shining, black varnish; or, better still, a number of diaphragms, according to the length of the camera, should be introduced, allowing the full cone, or pencil, of light proceeding from the lens, to fall upon the prepared plate uninterruptedly, whilst cutting off all reflections from the sides of the camera. The larger the diameter, or the more rapid the lens, the greater the importance of the above remarks.

Always carry the slide containing the prepared plate under a focussing cloth to the camera, and let this cloth remain on it when drawing up the shutter.

Now proceed to test the camera as to *register*. At a convenient distance place a sheet of newspaper or other clear print; carefully focus this on the screen. (A focussing glass, such as a Ramsden eye-piece of about 1 inch or 1½ inch focus, adjusted upon the greyed surface of the ground glass, should always be used for this purpose.) This done, remove the screen, and replace it by the dark slide; but instead of introducing the sensitized plate, put into the slide a piece of ground glass, ascertained to be perfectly flat. Now, observe whether the image appears as sharp on this as it did previously on the screen; if so, the camera is correct, or what is technically called in "register." If the image is not sharp, the position of the ground glass requires to be altered until it becomes so.

The common practice of *measuring*, by means of a rule, the distance between the camera front and screen, and then between the front and prepared plate in the collodion slide is quite inadequate to insure the necessary accuracy, especially for quick-acting lenses.

Care should also be used in the selection of the glass for the negatives, for it will be found that, even among "patent" plate, the percentage of really flat glasses is but small, more especially among the larger sizes.

Another source of error frequently exists in a too powerful *spring* on the door of the dark slide. This, when too strong, causes a bending of the prepared plate in the centre, and unfortunately this bending is just in the opposite direction to that required by the slight curvature of image produced by all lenses. Thick plates are, of course, less liable to bend than thin ones; but to be quite rid of this possible source of error, remove the *one* strong spring from the centre of the shutter, and replace it by *two* weaker ones, made to press equally on the two sides of the plate. Lenses are sometimes blamed for non-coincidence of foci, when the fault is really an imperfect camera, or a defective glass plate. It is hoped, however, that a little attention to the above will at once satisfactorily determine this point.

As regards the best position of the camera, a few hints may be of advantage, especially when it is required to take a standing figure; for no lens gives a perfectly flat field; hence the disposition of the camera requires great care, in order as much as possible to favour the action of the lens.

For a card portrait, using No. 2 B lens, distance of subject 18 feet, the camera being without a swing-back, arrange as follows:—

Height of centre of lens from the floor, about 4 feet 10 inches; rising front of camera elevated $\frac{1}{4}$ inch; let the image occupy the centre of the plate—*i.e.*, the head and feet equidistant from bottom and top of screen. To effect this, the camera requires tilting forward slightly. (Tilting the camera forward is an advantage, for it produces a more natural view of the face, and is preferable to its being placed lower and level, which latter position implies a

looking *up* into the face, and produces neither a natural nor pleasing picture. The image occupying the centre of the plate, proceed to focus for the eye, and then for the chest, or for some prominent object on the chest, a watch-chain for instance; now halve, as it were, the focus between this and the eye, when it will be found that the resulting picture will be evenly defined throughout its entire length.

The above is the actual *modus operandi* of one of our ablest portraitists, to whom I am indebted for the particulars.

For the cabinet portrait, standing figure, using a No. 3 B, No. 2 A, or No. 3 A lens, nearly the same conditions obtain; hence, the camera should be placed in the same position.

Photographers *compelled*, on account of insufficient length of studio, to use shorter focus lenses than the above—viz., a No. 1 B or No. 1 B long lens, for cards, and No. 1 A, for cabinets—should use the utmost care in adjusting the position of camera, for the use of shorter focus lenses implies a larger angle of definition. The above should be modified thus:—Height of centre of lens from floor, 4 feet 8 inches; rising front, elevated $\frac{1}{8}$ to $\frac{3}{16}$ inch; the rest as before.

A sitting figure requires the camera to be placed at a somewhat lower level, and here a swing-back to the camera is of great advantage. Indeed, portraits beyond the half-plate size should never be attempted without this adjunct; for, as stated already, the longer focus lenses are much more sensitive to any difference of distance than are the shorter focus ones, and in a sitting figure the feet are often as much as 24 inches in advance of the face. This occasions nearly $\frac{1}{4}$ of an inch of difference in the focus of a 20-inch lens. Hence, without a swing-back, allowing the top of screen or slide to be inclined outwards that distance, definition of the feet and legs simultaneously with the face is impossible.

In placing the accessories of a portrait, or in disposing the positions of a group of persons, regard should always be had to accommodate as much as possible the curvature of field produced by the lens; and this is accomplished by arranging the group of

accessories in approximation to a curve. That is, objects at the sides, should be brought nearer to the lens than those occupying the centre; the image then falls on a plane, and this is what is required. The amount of curvature of field varies in different lenses, and hence definite rules for placing the objects composing a picture cannot be given, but one or two trials will at once determine this question.

Another point deserving consideration is the following. A photographer accustomed to work with a short focus lens, on exchanging this for another of longer focus for the same sized plate, often complains of a want of brilliancy or roundness in his pictures. Now, in almost every instance this is simply a question not of lens, but of *lighting;* for a little consideration will make it apparent that the direction and amount of light suitable for a subject at a distance of 12 feet, require considerable modification when the distance is increased to 20 feet.

Then as to the time of exposure required by a lens—a question so frequently asked, but one which involves so many elements, viz., aperture of lens, lighting, chemicals, &c., that it is impossible to give a definite answer. A correct reply can only be given *relatively;* that is, if the time of exposure for a certain class of lens is known, then another kind of lens will require so much more or less, as the case may be, according to its construction. This information is to be found in my Catalogue where the lenses are classified according to their respective rapidities. If nothing relatively is known, then one or two experiments with the full aperture of the lens in question, is at once the readiest way to determine the point; and when ascertained for the full opening, the rule for finding it for any smaller-sized stops is given in the Catalogue.

VIEW LENSES.

The right choice among the many existing forms of view lenses requires the determination of the following points :—

1st.—The size of the picture.

2nd.—The angle of view, or amount of subject to be included in it.

3rd.—The kind of picture, whether landscape or architectural, or both.

As regards the first point, viz., "the size of picture," the professional photographer needs no information—he being guided by commercial considerations—but a few remarks addressed to the amateur on this head may be of service.

The beginner will find a small-sized plate, such as $7\frac{1}{4} \times 4\frac{1}{2}$ up to 10×8 inches, quite sufficient, being convenient for practice, and enough for producing artistic effects. The former of these sizes has the advantage of being adapted alike for a stereoscopic, or for one single picture.

In recommending the smaller sized plates, it may be well to remind the amateur that not only do the difficulties of manipulation greatly increase with any increased dimensions of plate, but that the quantities, weight, bulk, &c., of all the other necessary appliances become augmented also, and this in the proportion of more than the *square* for every increase of size of plate.

Secondly, "The angle of view" to be included in the picture. This depends upon the relation of its size to the focal length of the lens ; that is, the shorter the focus, the larger the angle, and *vice versâ.* The base line, or the longest side of the picture, is the measure of the angle included in it.

One of the principal and rightful claims of photography is its perfect truthfulness of delineation ; and yet, how frequently do we meet with pictures representing well-known objects or scenes, which at first sight are not even recognised ! This fact has been observed more frequently of late, *i.e.*, since the introduction of the wide-angle, or short-focus lenses. The cause of these *apparently* distorted views really turns upon the amount of angle included in

them, and hence there arises this question: What is the proper amount of subject, or angle, to be included in a picture?

The reply to this necessarily involves a consideration of the laws of perspective—a subject well worthy the attention of every photographer.

The following two propositions are sufficient for my present purpose:—viz., that the human eye itself is a miniature photographic camera, inasmuch as the several rays proceeding from objects, upon entering the eye, are refracted by its lens, and thence proceed to form a perfect image or picture on the smooth screen of nerve called the *retina;* and that it is by this picture that the mind is enabled to judge of the dimensions, brightness, colour, &c., of external objects. The angular extent of the picture formed upon the retina does not exceed 60° without some movement of the eye or head. Hence for a photograph to convey to the mind a correct idea of the objects represented, it should, when viewed at the normal distance of from 12 to 15 inches, excite the same impressions. Now the distance at which a picture is generally viewed will be found to be about equal to its base, or longest side; or, in other words, the angle it subtends for vision will be from 50° to 60°. This angle, therefore, should not be exceeded, for if more is included in the picture, the perspective will appear exaggerated, *i.e.*, objects in the foreground will be too large, and the distance becomes dwarfed.

To render it obvious that distortion of this nature is really no fault of the lens, such pictures need only be viewed at a distance equal to the focus of the lens with which they are taken, when all apparent distortion at once vanishes. This rule holds good in all cases, *i.e.*, every picture should be viewed at a distance equal to the focal length of the lens with which it is taken. Thus a 12 × 10 picture taken with a 7-inch focus wide angle Rectilinear Lens should be looked at, not at 12 or 15 inches, but at 7 inches distance from the eye.

From the above it is obvious that the only legitimate use for wide angle lenses is landscape photography; or, in other words, for such objects in which absolute truth is made subservient to beauty; but

for architecture, and the like, such lenses should be used only in case of necessity—*i.e.*, when the situation is so *confined* as to preclude the use of a longer focus lens.

As regards the choice of a *landscape lens*, all the most eminent landscape photographers are unanimous in recommending the "single combination" for simple landscapes, from the obvious reason that this lens, having but *two* reflecting surfaces, the rest being cemented, produces the most brilliant pictures; and, on account of its form, it has more depth of focus than a double combination lens. Further, the wide-angle single combination landscape lens produces an evenly defined picture with a comparatively large aperture. Hence, it is more rapid in action than the wide-angle double combination lens, which it surpasses, moreover, in equality of illumination throughout the entire extent of the picture.

The only drawback to this form of lens is a slight amount of perceptible distortion when used for objects bounded by straight lines, such as architecture, where the marginal lines will be slightly curved (barrel shaped). Hence, to avoid this, in a landscape with buildings, the latter should not be made to occupy the extreme margins of the picture.

Among the several kinds of single combination view-lenses extant, other things being equal, the *smaller* its diameter the better the lens.

As regards focal length, it has already been stated that this should not be less than the base line of the picture; that is, for a 10×8-inch plate, a 10-inch focal length lens, rather longer than shorter, should be chosen. The professional photographer, desiring the best possible results, must necessarily be provided with two or three lenses of different focal lengths for the same size of plate, *i.e.*, to *suit* his lens to the *subject;* and this is really the practice of all our best photographers. Thus I may mention, that for Mr. G. W. Wilson, of Aberdeen, I made as many as five pairs of different lenses for his stereoscopic pictures; viz., three pairs of quick-acting single combination landscape lenses, of $4\frac{1}{2}$, 6, and 8 inches focus respectively, and two pairs of wide-angle

Rectilinears of 3 and 4 inches focus. Mr. England uses similar lenses for his stereo' pictures; and for his well known 9×7 views, he employs no less than *five* lenses, as occasion requires, ranging from $5\frac{1}{4}$ up to 15 inches focus. Messrs. F. Good, Payne-Jennings, Valentine, and others, adopt the same practice.

For *architecture*, a rectilinear lens must, of course, be chosen, and for general use, one of moderate angle is to be preferred.

The Rapid Rectilinear is the best lens for that purpose, since it is free from distortion and flare, and works with a larger opening than any other kind of double lens. It is invaluable, therefore, for dark interiors, instantaneous effects, &c. Mr. Bedford and others have produced the most charming pictures with this lens, both of interiors and landscapes with buildings.

For *special* purposes, as for objects in confined situations, the wide-angle Rectilinear lens becomes indispensable; but for the reasons already given, it should be used only in cases of necessity. More than ordinary care, moreover, is requisite in the adjustment of the camera when wide-angle lenses are used.

The camera should, if possible, always be placed perfectly *level*, and the rising front employed, to take in the entire building; or if this proves insufficient, it is better to get on higher ground than to *tilt* the camera. If the camera *must* be tilted, a swing-back becomes indispensible to restore parallelism between the planes of the object, and screen or slide, otherwise all perpendicular marginal lines of the object will appear converging in the picture. Observe, the latter *modus operandi* taxes the lens to its utmost, and necessitates the use of a smaller stop. Of double combination lenses, that one is always to be preferred which, with the smallest diameter of lenses, really work with the largest aperture or stop, and covers the widest angle. [See my paper "On the cause of the central spot or flare," in the *Photographic Journal*, June 15th, 1867.]

If a lens is required for *general purposes*, as for landscapes, architecture, instantaneous views, groups, and portraits in the open air, then a double combination lens must be chosen; and for *out-door* work of this kind, I have no hesitation in stating that the

Rapid Rectilinear is the best lens an amateur, or a professional, photographer could fix upon.

All the instantaneous views by Messrs. Robinson, Gale, Hudson, Brownrigg, Bourne & Sheppard, Marsh Brothers, Mayland, Perkins & Son, A. Pringle, and others, were taken with the rapid rectilinear lens, and many excellent portrait studies have been taken with the same instrument. But for portraits in *the studio* it is scarcely sufficiently rapid in action, unless the very rapid dry plates are used, and if it be the aim to combine this and landscape photography, &c., in one and the same instrument, then a D patent portrait and group lens will probably best fulfil the several requirements. (See catalogue.)

For copying purposes, the rapid rectilinear lens is without a rival. It has already been supplied to *all* the Government topographical establishments in Europe, India and Australia. The two combinations composing this lens being perfectly *identical*, it is alike suitable for copying of equal size, or for reducing or enlarging.

One or two remarks about the proper use of a view lens, when the choice has been made:—

In the selection of a view, always aim as much as possible to favour the natural curvature of field as produced by the lens, *i.e.*, if possible let the side objects be nearest to, and the centre ones, farthest away from the camera. When photographing a flat object, say a block of buildings, or when copying a map or plan, focus for a point one-third from the centre; and the resulting picture will be approximately equal in definition throughout.

Always work with the largest possible aperture or stop, if you wish to secure relief and atmosphere in your picture. Proceed as follows: Focus for *the* object, *i.e.*, that which is to constitute the point of *interest* in the picture, and which is generally near in the foreground: do this with a medium stop; when done, look to the distance, and the other objects in the picture, and only reduce the aperture just so much as will prevent these appearing blurred; but do not aim at equal sharpness everywhere, if you wish to produce *a picture*. For, what artist ever paints his background or

accessories as sharp in outline as the subject of his picture? And who ever saw the distance perfectly sharp in nature when the eye is adjusted upon some object near in the foreground? Photography is claiming higher ground than the old standard of excellence, viz., *sharpness* everywhere; and those who aim at *artistic photography* may find the above hints of some service.

As regards the best kind of camera suitable for view lenses, that with the bellows body is the most convenient, being portable, and when well made, answering every purpose. Among these, perhaps, the *square* bellows body camera is preferable to that of the *conical*, or Kinnear form, inasmuch as the former can be used for lenses of very short focus, whereas the latter, when used for such lenses, frequently intercepts a portion of the cone of rays, and spoils the picture.

For directions of testing the camera, &c., see remarks on this subject under the heading "Portrait Lenses."

APPENDIX.

To find the *angle of view*, or the amount of subject included in a picture, ascertain the equivalent focus of the lens, and measure the base line of the picture. Upon a sheet of paper draw a line of the same length as the latter, bisect it, and let fall a perpendicular exactly equal in length to the equivalent focus of the lens; join the extremity of bisected line and perpendicular by another line; now apply a protractor, and measure the angle included between these two lines, and the angle read off, multiplied by two is the angle included in the picture. Or, with the data known as above, and a table of natural sines and tangents at hand, divide half the base line of the picture by the equivalent focus of the lens; find in the tables under the heading "tangents" the same number as the above quotient, and the corresponding angle, multiplied by two, is the angle included in the picture.

The following particulars may be of service:—

If the base line, or the longest side of the picture, is equal to the equivalent focus of the lens, the angle included is 53°; if the

base line measures $1\frac{1}{4}$ the equivalent focus, the angle is 64° ; if $1\frac{1}{2}$ it is 74° ; if $1\frac{3}{4}$ it is 82° ; if twice it is 90°.

Depth of focus, or depth of definition, is dependent upon the aperture and the focal length of a lens. It increases in the same ratio as the diameter of the aperture is reduced, and it diminishes as the square for any increase in the size of the picture, or the focal length of lens. Hence, the shorter the focal length, other things being equal, the greater the "depth," or the nearer may be an object in the foreground; beyond which everything else will be in practically good focus.

The *rapidity* of a lens depends upon the relation, or the ratio, of aperture to the equivalent focus. To ascertain this, divide the *equivalent focus* by the diameter of the actual *working aperture* of the lens in question ; and note down the quotient as the denominator of a fraction with 1, or unity, for the numerator. Thus : to find the ratio of a lens of 2 inches diameter and 6 inches focus, divide the focus by the aperture, or 6 divided by 2 equals 3 ; *i.e.*, $\frac{1}{3}$ is the intensity ratio. Another lens, of 4 inches diameter and 24 inches focus, has $\frac{1}{6}$ for its intensity ratio ; and this ratio once ascertained, it only remains to multiply each denominator by itself to find their comparative rapidities. As above, the ratio of the 2-inch lens is $\frac{1}{3}$, or 3×3 equals 9 ; the ratio of the 4-inch lens is $\frac{1}{6}$, or 6×6 equals 36 ; therefore, if the 2-inch lens requires 9 seconds exposure, the 4-inch lens necessitates 36 seconds ; or, in other words, the 2-inch lens is four times quicker acting than the 4-inch.

It must be observed, however, that in order to find the real *intensity ratio*, the diameter of the actual working aperture must be ascertained. This is easily accomplished in the case of single lenses worked with *front* stops, or for double combination lenses used with the *full* opening, these merely requiring the application of a pair of compasses or rule ; but when double or triple combination lenses are used, with stops inserted *between* the combinations, it is somewhat more troublesome ; for it is obvious that in this case the diameter of the stop employed is not the measure of the actual pencil of light transmitted by the front combination.

To ascertain this, focus for a distant object, remove the focussing screen, and replace it by the collodion slide, having previously inserted a piece of cardboard in place of the prepared plate. Make a small round hole in the centre of the cardboard with a piercer, and now remove to a darkened room; apply a candle close to the hole, and observe the illuminated patch visible upon the front combination; the diameter of this circle, carefully measured, is the actual working aperture of the lens in question for the particular stop employed. The operation must, of course, be repeated for any other sized stop that is inserted between the lenses.

It would be of great advantage to photographers generally, if, in the description of experiments, &c., the above *intensity ratio* were always recorded, as it is the only real standard of comparison between the rapidities of different lenses.

The *back focus* of double-combination lenses, as, for instance, ot a portrait lens, depends upon the separation or interval between the two combinations; it is, therefore, a variable quantity, and cannot be taken as a measure of comparison between lenses of different construction. The true standard of comparison for double or multiple combination lenses is what is termed the *equivalent focus* or the *equivalent focal length*, viz., that quantity, or length, which is equal to the *solar focus* (or the focus for parallel rays) of a thin single lens, such as a spectacle eye-lens. Hence the name equivalent focus.

Since, however, the size of an image produced by any lens is always in exact proportion to its equivalent focus, the latter can readily be determined, if the former is known, and *vice versâ.* To judge, then, of the comparative focal length of any two lenses, we have only to place them side by side and to compare the size of their respective images, both pointing to the same object. For example:—

A spectacle eye-lens has a solar focus of exactly 10 inches, and the size of image produced by it of some distant object measures 4 ins. in height; the same object focussed upon with a portrait lens measures 8 inches on the screen. Required, the equivalent focus

of the portrait lens. Then, by simple proportion, as the size of image of the one is to that of the other, so also are their foci, or as 4 : 8 : : 10 : 20 inches ; the *equivalent focus* of the portrait lens in question.

The above method affords a ready means of comparing the relative focal lengths of different lenses when placed side by side ; but to arrive at the absolute equivalent focus of a given combination is somewhat more troublesome, and involves the possession of a single lens, the solar focus of which has to be measured with great care.

There is, however, a readier mode for ascertaining the absolute equivalent focus of any combination lens, and this, with sufficient accuracy for almost every purpose ; besides which, no adjunct is required other than that in the possession of every photographer. It depends upon a law in optics; namely, that when the size of the image produced by a lens is exactly equal to that of the object, then the distance between the object and the focussing screen measures exactly four times the equivalent focus of the lens.

To find the equivalent focus of a given lens, proceed as follows :—Take a flat piece of wood, as a drawing board, with a piece of paper stretched upon it, place it before the camera, and adjust it at right angles to the lens in two planes, as is customary for copying pictures or maps. Draw two lines at right angles to each other upon the paper, and see that the point of intersection coincides with the axis of the lens and the centre of the focussing screen. On each side of the centre of one of the lines, measure and mark off with a pair of compasses a certain distance, equal to about one-fourth of the base line of the focussing screen. Now proceed, as in copying, for equal size or scale, *i.e.*, adjust the distance between lens and object, and lens and screen, until the image of the mapped line on the screen, *when sharply defined*, is exactly equal in length to that on the paper. The pair of compasses already made use of, answers the purpose. Now remove the lens, and carefully measure the distance between the paper and the focussing screen ; and *one-fourth* of this distance is the *equiva-*

lent focus of the lens in question. The approximate *optical centre* of the lens can be determined at one and the same operation. For this purpose replace the lens, without altering the arrangement, and make a mark upon the mounting or tube exactly equal to *one-half* the distance between the paper and focussing screen, measuring from the former. This point marked upon the lens-tube indicates the approximate optical centre of the combination, and is, in fact, the zero from which to calculate or to measure the distance of the object and the focussing screen, either for enlarging or for reducing to a given scale.

To find the exact positions of the object and the focussing screen, both measured from the optical centre of the lens, for a given enlargement, add 1 to the number of times you wish to enlarge, which, multiplied by the equivalent focal length of the lens, gives the position of the focussing screen, or indicates the required length of the camera; and this length divided by the number of times of enlargement, gives the position of the object that is to be enlarged. Thus: Required to enlarge a 5×4 negative four times (*i.e.*, to 20×16 inches), with an 8-inch equivalent focus lens; then to 4 add 1, equals 5, multiplied by 8, equals 40 inches, or the length of the camera or position of the focussing screen; and 40 divided by 4 equals 10 inches, the distance at which to place the negative from the optical centre of the lens. For *reducing*, the positions of object and focussing screen are as follows:—Add 1 to the number of times you wish to reduce, and multiply by the equivalent focus of the lens, the product gives the distance of the object from the lens; and this, divided by the number of times you wish to reduce, indicates the position of the focussing screen or the length of the camera. In the above example, we have only to change the place of object for the screen, and *vice versâ*, when the positions are correct for reducing to $\frac{1}{4}$ scale.

In copying transparencies, carefully guard against any other but *parallel* rays being made use of for the formation of the image. To effect this, place a parallel box of light wood or paper projecting a considerable distance in front of the transparency; the box should be blackened inside, or, better still, lined with velvet, or provided

with several diaphragms with openings of the same size as the transparency.

Always endeavour to shade the lens as much as possible, *i.e.*, keep from it all extraneous light not actually used for the formation of the image, and the resulting picture will have its brilliancy proportionately augmented. This remark applies more especially to double or multiple-combination lenses.

The glasses composing a lens should be free from veins, striæ, &c., and the several surfaces should be well polished by the optician; any remaining dull or grey appearance after careful wiping indicates defective polish. The presence of a few air bubbles *does not in any way affect the performance of* a lens; but unfortunately, every one can see these, whereas other defects much more detrimental can only be detected by a practised eye. The more limpid or colourless the glass, the better the lens.

The fewer the number of reflecting surfaces, other things being equal, the greater the brilliancy of the resulting picture.

The smaller the diameters of double combination lenses, and the nearer that they are placed together, other things being equal, the greater the freedom from flare.

Never expose lenses to the prolonged action of sunlight [See my paper, "The effect of sunlight upon glass," in the *Year-book of Photography* for 1880]. Keep the lenses as much as possible in a *dry* atmosphere, and guard against sudden changes of temperature, otherwise some kinds of glass are liable to tarnish, or, what is technically termed, to "sweat." Whenever any moisture becomes visible upon any surface, at once remove it by wiping with a *soft* cambric or old silk handkerchief; otherwise resort to wiping *only* when particles of dust adhere so firmly to the glass that they cannot be removed with a camel's hair brush. Never attempt to polish the lenses with any kind of powder whatever.

ON THE USE OF DIAPHRAGMS OR STOPS.

Stops or diaphragms, judiciously employed, are among the most valuable requisites of the photographer ; for it is by their aid that faults can be corrected, and difficulties surmounted. It must be borne in mind, however, that stops do not cure every defect ; and that the most perfectly constructed lens, *per se*, either always admits of the use of the largest stop, or, for equal apertures, gives the best results.

Aplanatic lenses, or lenses free from aberration, need no stop to improve the definition of the central parts of the picture ; and hence, as in the case of portrait, group, or rapid rectilinear lenses, there should be no fixed stop permanently contracting their apertures.

It is otherwise with what may be called *landscape lenses* proper, and to these, more especially, the following remarks are intended to apply. To begin with the *single* combination :—This lens is of such form, and placed in such a position, that it cannot be used without a stop, even for the centre of the picture ; and the same may be said of wide-angle double-combination lenses.

I.—VIEW LENSES.

The stop affects the picture (1) by its *position*, influencing distortion, illumination, and flare ; and (2) by its *size*, determining exposure, definition, and depth of focus.

The stop, when placed immediately in contact with the single view lens, simply reduces the diameter of the lens, and in consequence, the picture gains in sharpness in the centre only ; for in this position the margins are depicted by oblique but axial pencils of light, and the field of view is too much curved to admit of its reception on a flat screen, though there is no distortion.

It is otherwise when the stop is removed some distance, say from $\frac{1}{4}$ to $\frac{1}{7}$ the focal length, in *front* of the lens. In this position the stop not only limits the diameter of the pencils of light falling

upon the lens, but it causes them to cross the axis at the place of the stop, before refraction; whereby different parts of the object, or landscape, are depicted by corresponding different parts of the lens; as, the centre by the centre, and the margins by the margins. In other words, eccentrical instead of central oblique pencils are now made use of, and hence results flatness of field, proportionate in a degree to the distance of the stop from the lens. Unfortunately, however, flatness of field so obtained is accompanied by two drawbacks, viz., contraction of the angle of picture, and "barrel"-shaped distortion. If the stop is placed at the same distance *behind* the lens, it is obvious that the image-forming rays cross the axis after refraction, and the result is the opposite kind, or "pincushion"-shaped distortion. Hence that form of single view lens is to be preferred which, while it gives the necessary flatness of field, permits of the closest approach of the stop. For equal diameters of lenses, it also embraces the largest angle.

One point must not be overlooked, when the stop is placed in front of the lens, viz., the presence of "flare," caused by internal reflections at the surfaces of the lens, and producing an image of the stop aperture. When this image happens to coincide with the focus of the lens, it makes its appearance as a "flare-spot" in the centre of the picture, more especially noticeable when small stops are used. The formation of the flare-spot depends upon the distance of the stop from the lens, and if present with any lens, it can easily be got rid of by a slight alteration in the distance of stop. One eighth of an inch of difference either way will generally be found sufficient to obliterate it.

The above remarks regarding the position of the stop, and its effect upon the picture, equally apply to wide-angle, double-combination view lenses. A little consideration suffices to show that distortion in these is got rid of by the opposing errors of the front and back combinations, with reference to the position of the stop; the condition being, that the axis of the several emergent pencils of light, after refraction, are parallel to the incident ones. If the two combinations are symmetrical, as is the rapid rectilinear, the proper position of the stop is equidistant from the front and

back lenses; and if unsymmetrical, its place is proportionate to the foci of the combinations. Flatness of field and angle of view, or illumination, depend upon the separation of the lenses, or their respective distances from the stop, as in the case of the single view lens. An increase of separation tends to greater flatness of field, but is accompanied by a reduction of angle of view and the converse. The proper separation of a double combination lens is, however, generally determined by the maker; and it should not be altered except under special circumstances of need.

It has already been stated that the single combination view lens has one reflex image, whereas in a double combination there are six; two of which may produce "flare," and should be guarded against. If present, the same remedy applies, viz., a slight alteration of the distance of stop, or separation of the two combinations, as by unscrewing the back combination. It follows that the single combination view lens, producing but one reflex image, gives the most brilliant picture.

One other consideration in regard to equality, or rather *non-equality*, of illumination must be noticed. Wherever the stop may be placed, either in front of the single lens, or between a double combination lens, it does not permit the passage of an equal amount of light. Thus the centre of the picture is depicted by light equal to the full area of the stop, but as the rays fall more and more obliquely upon the stop, forming the margins of the picture, the light transmitted becomes less and less.

This diminution of the light at the margins is further augmented by the necessarily increased focal length of the pencils depicting that part of the picture, to accomodate for flatness of field. The diminution of light from the centre towards the margins of the picture, from both these causes, increases rapidly with any increase of angle of view beyond 40°. At this obliquity, the extreme margins only receive 80 per cent. of the light falling upon the centre; at 50° it is reduced to 70 per cent.; at 60° to 55 per cent.; at 70° to 45 per cent., or less than one-half. Therefore the larger the angle included in the picture, the more apparent becomes this defect.

For equal angles of picture, the single combination, with a front stop, has the advantage, as regards equality of illumination, over double combination lenses; and among the latter class, some lenses will be found superior to others in this respect, owing to their construction, *i.e.*, their diameters, forms, &c.

Next, the effect of *size*, or aperture of stop, has to be noticed, and what follows applies equally to single and double combination lenses.

The proper shape of the stop is a round aperture, and its size controls the area of light transmitted by the lens, thus regulating the exposure. The aperture of the stop should always be stated in terms expressing the ratio of the diameter of the stop to the equivalent focus of the lens. It is convenient for reference and comparison of different lenses, and all that is needed for its determination is to divide the focal length of the lens by the diameter of the stops. Thus a 10-inch focus and a 1-inch stop, the ratio or the intensity $=\frac{1}{10}$. A 10-inch focus, and $\frac{1}{2}$-inch stop $=\frac{1}{20}$. The denominators of these fractions multiplied by themselves at once give the relative exposures; as above $10 \times 10 = 100$; $20 \times 20 = 400$; therefore a 10-inch focus lens with a $\frac{1}{2}$-inch stop requires four times the exposure of a 1-inch stop. Similarly a 20-inch lens and a 1-inch stop $=\frac{1}{20}$ works in the same time as does a 10-inch lens and a $\frac{1}{2}$-inch stop.

The aperture or diameter of stop also determines the amount of depth of focus, and this increases in the same proportion as the diameter of stop diminishes. Hence, twice the "depth of focus" can only be had at the expense of four times the exposure. This originates with a law in optics—one that cannot be set aside —viz., that for every varying distance of the object from the lens there is a corresponding different focus also. Thus every point in an object out of focus is represented in the picture by a disc, or circle of confusion, the size of which is proportionate to the aperture in relation to the focus of the lens employed. If a point in the object is $\frac{1}{100}$ of an inch out of focus, it will be represented by a circle of confusion measuring but $\frac{1}{100}$ part of the aperture of the lens; and when the circles of confusion are sufficiently small

the eye fails to see them as such; they are then seen as points only, and the picture appears sharp. At the ordinary distance of vision, of from twelve to fifteen inches, circles of confusion are seen as points, if the angle subtended by them does not exceed one minute of arc, or roughly, if they do not exceed the $\frac{1}{100}$ of an inch in diameter.

Assuming this to be the limit of permissible indistinctness or want of focus, it is easy to calculate, for any lens and aperture, the distance that the nearest object in the foreground may approach the lens, when everything beyond, or further off, will also be well defined in the picture.

The following table may be of interest as showing this distance at a glance for the focal lengths of lenses and apertures mostly used for views:—

Intensity or Aperture-Ratio.	Relative Exposure.	Focal Length of Lenses in inches.								
		4	6	8	10	12	15	18	21	24
		Distance of Nearest Object in feet (Approximate.)								
$\frac{1}{10}$	1	14	31	54	84	121	189	272	368	482
$\frac{1}{15}$	2	9	21	36	56	81	126	182	247	322
$\frac{1}{20}$	4	7	16	27	43	61	95	137	186	242
$\frac{1}{30}$	8	5	11	18	29	41	64	92	124	162
$\frac{1}{40}$	16	4	9	14	22	31	48	69	94	122

For example: it is required to know the distance of the nearest object in the foreground, beyond which everything will be defined, for a lens of ten inches focus and $\frac{1}{2}$-inch stop, intensity $= \frac{1}{20}$. Find $\frac{1}{20}$ in the first column, and pursue this line to the column headed 10; the corresponding figure here is 43 feet, or the distance sought. If the same lens is to be used with a $\frac{1}{4}''$ stop, intensity $= \frac{1}{40}$, the corresponding figure is 22 feet.

The second column shows the approximate exposures. In the first case it is 4, in the second 16. Thus a reduction of one-half in diameter of stop gives double the depth of focus, but at the expense of four times the exposure.

It is necessary to remark here that "depth of focus," as shown above, only applies to lenses with a flat field, accurately centred

and free from flare; and this points to the remarks at the beginning of this article, viz., that the most perfectly constructed lens always produces the best results.

One practical hint in conclusion, and where the tabular distances, &c., as above, are of no avail. Always use the largest possible stop in order to secure vigour, roundness, and atmospheric effect in the picture. A small stop produces sharpness, but at the expense of the foregoing essential qualities. As a rule, focus for some prominent object in the foreground, or upon that which is to constitute the point of interest in the picture. Do this with a medium stop, then insert the next, or the next but one smaller, sufficient to prevent objects not focussed upon appearing too much blurred, thus marring the picture.

II.—PORTRAIT LENSES.

The essential difference between portrait and double combination view lenses is increased intensity, or greater angular aperture; and expressing this in the same terms as used above, portrait lenses up to 9″ focus are constructed with intensity ratio $= 1/2$ (*i.e.*, 1 inch of aperture for 2 inch focal length), or $= 1/3$ for lenses up to 15 inch, or $= 1/4$ to $1/6$ for larger or longer focus lenses; whereas in view lenses the intensity ratio is only from $1/8$ to $1/40$.

The increased aperture of portrait lenses, however, is accompanied by some serious drawbacks; and among these are non-equality of illumination of field and want of depth of focus; both curable, however, to a certain extent, by the judicious use of stops, as will appear farther on.

The correction for aberration in a portrait lens necessitates a greater interval, or distance, between its two component elements or combinations; and a little consideration suffices to show that this increased separation occasions a rapid falling-off of light from the centre towards the margin of the picture:—Thus a lens, intensity $1/3$, equally illuminates a central spot of 12° only; at 32° this illumination is reduced to one-half, and beyond this it

diminishes again, until at 52° it ceases altogether. These angular values, expressed in inches of circular area for a $3\frac{1}{2}''$ lens of $12''$ equivalent focal length, are (in round numbers) $2''$, $6\frac{1}{2}''$, and $13''$.

Fortunately for the photographer, equality of illumination is of little moment when the requirement is a bust or even a figure in a sitting posture; but it is otherwise when standing figures or groups have to be taken. In the latter case the light must be more equally distributed, to avoid crowded shadows.

The remedy, and indeed the only available remedy, is the use of stops, smaller and smaller in size as the picture grows larger, until a too prolonged exposure forbids a farther reduction of diaphragm aperture. Thus for the lens already referred to, a $2\frac{1}{4}''$ stop (double exposure) only equally illuminates a circular patch of $3\frac{1}{2}''$ diameter; while a $1\frac{1}{2}''$ stop (four times the exposure) gives equal illumination over an area comprised within a circle of $6\frac{1}{2}''$ diameter.

Hence it is obvious that for rapid exposures the size of the picture is limited to the diameter of the lens, and this is practically adhered to by those photographers who are using a $2\frac{3}{4}''$ lens for cards, and a $3\frac{1}{2}''$ or $4''$ lens for cabinet pictures.

So much for the use of stops in effecting equality of illumination; the next and most important consideration remaining to be noticed is its use for effecting depth of focus. It may be as well to remind the reader that, according to a fixed "law" in optics, every difference of distance of object from the lens is accompanied by a correspondingly different focal length of that lens, or, in other words, a perfectly corrected lens, strictly speaking, has no depth of focus. But a *solid* cannot be photographed without some depth of focus, and the point to be determined is, how much one may depart from the true focus without producing sensible indistinctness, or want of focus, in the picture. This done, the corresponding variation in the distance of object is readily determined by calculation.

The limit of indistinctness adopted in the previous article was a circle of confusion not exceeding 1-100th of an inch in diameter.

For at a distance of from 12 to 15 inches such a circle appears to the eye as a point, and, therefore, objects so much out of focus appear sharp in the picture. The same limit of indistinctness has been adopted for the computation of the table following; though for shorter focus lenses, or for smaller pictures, it is, perhaps, in excess of what is permissible, inasmuch as such pictures are often viewed at one-half the above distance only; and the limit of indistinctness is reduced by one-half also. Since, however, the table only shows the available depth of focus *behind* the point focussed upon (to prevent an overcrowding of figures), and as there is an almost equal amount of "depth" in *advance* of the point of object focussed upon, making up the "total depth," which is equal to about twice that given in the table, the photographer who desires a sharper picture has only to consider the depths given for the shorter focus lenses, representing their total depths, or to halve this quantity for depth *behind* the point focussed upon. In any case, for a perfectly corrected lens of a given focal length and aperture, the depth of focus *behind* the point focussed upon, for the several distances of object contained in the table, is the utmost that can be expected.

One other point in regard to the use of the table remains to be noticed. It is this: that the depth of focus given only applies to a lens having a perfectly *flat* field, and as such a lens does not exist, and cannot be made, it follows that the depth only applies to the "centre" of the picture, or to objects coincident with the axis of the lens. Or the photographer must arrange the objects composing his picture in a curve, *i.e.*, the side objects nearer to, and the centre ones farther off, to suit the curvature of field as produced by the lens, when the image falls upon a plane, and the rule applies :—

Equivalent Focus of Lens in *inches.*	Intensity or Aperture Ratio.	Relative Time of Exposure.	Distance of object in *feet.* 10	12	14	16	18	20	24
			Depth of Focus in inches *behind* the point focussed upon.						
6	$\frac{1}{2}$	4	7	11	16	21	28	35	52
	$\frac{1}{3}$	9	12	18	25	34	43	57	87
	$\frac{1}{4}$	16	16	24	33	48	62	76	116
	$\frac{1}{5}$	25	17	30	42	57	71	95	145
	$\frac{1}{6}$	36	24	36	50	68	86	114	174
	$\frac{1}{7}$	49	28	42	58	79	100	133	203
	$\frac{1}{10}$	100	40	60	83	113	143	190	290
9	$\frac{1}{2}$	4	3	$4\frac{1}{2}$	$6\frac{1}{2}$	8	11	14	20
	$\frac{1}{3}$	9	4	7	10	13	17	21	32
	$\frac{1}{4}$	16	5	9	13	17	23	28	43
	$\frac{1}{5}$	25	7	12	17	22	28	35	53
	$\frac{1}{6}$	36	8	14	20	26	34	42	64
	$\frac{1}{7}$	49	9	16	23	30	39	49	74
	$\frac{1}{10}$	100	13	23	33	43	56	70	106
12	$\frac{1}{3}$	9	$2\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{4}$	7	9	12	17
	$\frac{1}{4}$	16	3	5	7	9	12	16	23
	$\frac{1}{5}$	25	3	7	8	12	15	20	28
	$\frac{1}{6}$	30	4	8	10	14	18	24	34
	$\frac{1}{7}$	49	5	9	12	16	21	28	40
	$\frac{1}{10}$	100	7	13	17	23	30	40	56
15	$\frac{1}{3}$	9	$1\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{1}{4}$	$4\frac{1}{4}$	$6\frac{3}{4}$	7	10
	$\frac{1}{4}$	16	2	3	4	5	8	9	13
	$\frac{1}{5}$	25	$2\frac{1}{2}$	$3\frac{1}{4}$	5	7	10	12	16
	$\frac{1}{6}$	36	3	$4\frac{1}{2}$	6	8	12	14	20
	$\frac{1}{7}$	49	$3\frac{1}{2}$	$4\frac{5}{8}$	7	9	14	16	26
	$\frac{1}{10}$	100	5	$6\frac{5}{8}$	10	13	20	23	33
18	$\frac{1}{4}$	16	$1\frac{1}{4}$	2	$2\frac{7}{8}$	$3\frac{7}{8}$	5	$6\frac{1}{4}$	$9\frac{1}{4}$
	$\frac{1}{5}$	25	$1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{5}{8}$	$4\frac{7}{8}$	$6\frac{1}{4}$	8	$11\frac{3}{4}$
	$\frac{1}{6}$	36	$1\frac{7}{8}$	3	$4\frac{1}{4}$	$5\frac{3}{4}$	$7\frac{1}{2}$	$9\frac{3}{8}$	14
	$\frac{1}{7}$	49	$2\frac{1}{4}$	$3\frac{1}{2}$	5	$6\frac{3}{4}$	$8\frac{3}{4}$	11	$16\frac{1}{4}$
	$\frac{1}{10}$	100	$3\frac{1}{8}$	5	$7\frac{1}{8}$	$9\frac{3}{4}$	$12\frac{1}{2}$	16	$23\frac{1}{4}$
21	$\frac{1}{4}$	16	1	$1\frac{1}{4}$	2	$2\frac{5}{8}$	$2\frac{7}{8}$	4	$6\frac{5}{8}$
	$\frac{1}{5}$	25	$1\frac{1}{4}$	$1\frac{5}{8}$	$2\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{2}$	5	$8\frac{1}{4}$
	$\frac{1}{6}$	36	$1\frac{1}{2}$	2	3	4	$4\frac{1}{4}$	6	10
	$\frac{1}{7}$	49	$1\frac{3}{4}$	$2\frac{1}{4}$	$3\frac{1}{2}$	$4\frac{5}{8}$	5	7	$11\frac{5}{8}$
	$\frac{1}{10}$	100	$2\frac{1}{2}$	$3\frac{1}{4}$	5	$6\frac{5}{8}$	$7\frac{1}{8}$	10	$16\frac{5}{8}$
24	$\frac{1}{4}$	16	$\frac{5}{8}$	1	$1\frac{1}{2}$	$1\frac{5}{8}$	$2\frac{1}{2}$	$3\frac{1}{4}$	5
	$\frac{1}{5}$	25	$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{7}{8}$	$2\frac{1}{8}$	$3\frac{1}{8}$	4	$6\frac{1}{4}$
	$\frac{1}{6}$	36	$\frac{7}{8}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{3}{4}$	5	$7\frac{1}{2}$
	$\frac{1}{7}$	49	1	$1\frac{3}{4}$	$2\frac{5}{8}$	3	$4\frac{3}{8}$	$5\frac{3}{4}$	$8\frac{3}{4}$
	$\frac{1}{10}$	100	$1\frac{1}{2}$	$2\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{1}{8}$	$6\frac{1}{4}$	$8\frac{1}{8}$	$12\frac{1}{2}$

The table is constructed for the portrait lenses in general use, *i.e.*, from 2″ to 6″ diameter, with corresponding foci, worked at the usual distances from the subject, commencing at 10 feet. The intensity begins with 1/2 for lenses up to 9″ focal length; then 1/3 up to 15″ and for 1/4 beyond. The first row of figures in each line, for the several lengths of foci given, has been calculated; the rest are found by proportion, and fractions smaller than 1-8″ are omitted.

To use the table, it is only necessary to ascertain the equivalent focal length of the lens in question, and to divide this length by the aperture or diameter of stop used; the quotient written down in the form of a fraction with 1 for the numerator gives the intensity. Then to measure the distance between the lens and sitter. Thus, let it be required to find the depth of focus behind the point focussed upon for a lens of 2″ diameter and 6″ equivalent focus, the sitter at 12 feet from the lens. As above 6 ÷ 2=intensity 1/3, now find focus 6″ in the table; the second line has intensity 1/3; exposure 9, and the corresponding figure on the same line for a distance of 12 feet is 18 in., or the depth of focus sought.

Or, again: required the depth for the same lens, using a 1″ stop for a sitter at the same distance. Then 6 ÷ 1=intensity 1/6, and for this the corresponding figures—*i.e.*, refer to the fifth line of the table—are exposure 36, depth=36 in., the answer required. A glance along the several lines of figures of the table at once exhibits the rapid falling-off of "depth" as the image or picture is enlarged either by approach of the object or by the use of longer focussed lenses. Thus, for instance, a perfectly corrected lens of 6″ diameter and 24″ focal length, with full aperture, the sitter at 12 feet, only has a "depth" of 1 inch; demonstrating, beyond question that large pictures will always be inferior to small ones in definition; and that to be produced at all satisfactorily, something must be devised to increase the depth of focus as per table. The result of an effort in this direction was the portrait lens introduced in 1866.

ON THE USE OF A SWING-BACK TO THE CAMERA.

The addition of a swinging back to the Camera is so important a factor in influencing the most advantageous use of the lens, that I have added a few remarks on its functions.

The question frequently occurs : " What is the use of a swinging-back to the camera?" In what follows, I propose to answer this question; but before I proceed, it may be advantageous first to define the meaning of a swing-back.

Briefly, it is a contrivance at the back of the camera which admits of an inclination of the groove containing the screen, or slide, with reference to the axis of the lens. If the swing, or inclination, is confined to one plane, it is a single swing-back; if free to move in both planes, viz., upon a horizontal and vertical axis, it constitutes a double swing-back. To attain the same end other expedients have been devised, such as curved fronts, hinged fronts, &c., in each case substituting a moving or swinging lens for a swing-back. But these can only be classed among the *make-shifts* and should be avoided.

A little consideration suffices to show that any movement or inclination of the lens at once *displaces* its axis with reference to the centre of the plate or picture ; and, apart from this, a movement of the lens is much more difficult to control. It may fitly be compared to the laying hold of the *short* end of a lever; and no mechanic would resort to such a practice.

In fine, the lens or the camera-front, with the exception of the usual rising front, should be a fixture by construction, made truly square with the base and sides of the camera. The swing-back, as its name implies, properly belongs to the *back* of the camera, and if the centres of motion of the swing are coincident with the axis of the lens, or the centre of the plate, as in the old construction of portrait cameras, so much the better.

A swing-back, judiciously used, can be made to answer the

same purpose as a smaller stop, *i.e.*, objects situated at different distances from the lens can be brought to in focus by its aid.

For example: required to take with a 16″ focus lens, a 12 × 10 picture of a row of houses, say the side of a street, with the nearest house at a distance of 50 feet, and the farthest half-a-mile off. Every photographer knows that the object close at hand requires the camera to be drawn out, or has a longer focus than the distant one; in this case the difference of focus amounts to nearly half-an-inch, so that, without resorting to the use of a very small stop $\frac{F}{40}$, it is impossible to obtain a sharp picture. If, now, the mid-distance be focussed for with a stop $\frac{F}{20}$ on the centre of the plate, and the swing-back is brought into action, by throwing out the right-hand side of the screen or slide $\frac{1}{4}$in., and then bringing the left that much nearer—by a swing of the back upon its vertical axis—the varying distances of object have their corresponding different lengths of foci, and the picture is sharply defined throughout its entire extent.

Or again; it is desired to take a picture of some interesting view, composed of some rustic building, or clump of trees to the foreground, close to the camera, with the mid-distance occupied by hills, &c., stretching into the distance on the right. Here again, the swing-back affords the means to get good definition with a comparatively large aperture; for in this case we have only to focus for the mid-distance, then to swing the right out and the left in to compensate for the differences of focus between the near and distant objects, when we obtain a well-defined picture full of vigour, atmospheric effect, &c., otherwise impossible. Or, once more:

Let there be some foreground object comparatively close to the camera, while the rest of the landscape stretches into the distance. Now we require the swing in the other direction, viz., on its horizontal axis; for, by throwing out the top of the screen, and pushing in the bottom, we accomodate the focus for the near and distant objects, thus securing good definition throughout. Other instances might be cited, but the above examples are sufficient to prove the value of a swing-back for views.

For portraiture the swing-back is even of greater importance, for to secure a *likeness*, rapidity in conjunction with definition is indispensable; and any mechanical aid which favours the obtaining of the latter, practically augments the former. Any one who has glanced at the foregoing table of the depths, will have been struck with the comparatively *small* gain in "depth" obtained by the use of smaller stops; and how dearly this is purchased by prolonged time of exposure. For example: required to take a whole-plate portrait in a sitting posture, with a 4-inch lens of 12-inch focus, or aperture ratio $\frac{1}{3}$. Suppose the head, or eyes, at a distance of 12-feet, and the feet of the sitter projecting some 18 inches, *i.e.*, at 10 feet 6 inches from the lens, to get a visually sharp picture of the entire person a depth of 18 inches is required, or by halving the focus between the eyes and feet 9 inches each way. On reference to the table above referred to it will be found that the figure answering to this focal length and distance of object is $\frac{1}{7}$, that is, the 4-inch lens must be stopped down to $1\frac{3}{4}$-inch aperture, when the corresponding exposure becomes *five* times that of the full opening. If now the swing-back is brought into action, we have the means of throwing out the top of the screen, corresponding to the feet of the sitter, while the head remains in focus, and this with a much larger aperture; a depth of 5 inches being sufficient, and the corresponding aperture ratio is $\frac{1}{4}$, *i.e.*, a 3-inch stop now suffices, requiring only about *double* the exposure of the full opening. The gain in rapidity between the aperture ratios of one-quarter and one-seventh being as 16 seconds are to 49 seconds.

Examples might be multiplied, showing the advantages of swing-back for a sitter placed sideways, with one arm and hand projecting in advance of the other, when the camera back must be swung upon its vertical axis. Or, when a group of persons are to be taken, in which case both the horizontal and vertical motions may be advantageously used. Suffice it to state that the importance of the swing-back addition to the camera becomes greater and greater with every increase of size of plate, or focal length of lens. That is to say, the sensitiveness of focus for varying distances of objects increases as the square of the focal length

employed, *i.e.*, a 20-inch focus lens has only one quarter the depth of a 10-inch. Hence the swing-back proves a great acquisition, both for views and portraits, for plates 10×8 and upwards.

There are, however, occasions when the swing-back is either wholly useless, or, at any rate, had better be dispensed with. To the former category belongs the copying of maps, plans, &c., requiring a *rigid* back to the camera, always remaining accurately square and parallel to the front. In regard to the latter, viz., dispensing with the use of the swing back, the following case may serve as an illustration. Let it be required to photograph the facade of some high building, the top of which is not included in the picture. Now, instead of tilting the camera, it is better to keep it level, and first to resort to the use of the rising front to its utmost extent, and next, if this prove insufficient, to get on higher ground. For, if perpendicular lines of the object are to be parallel in the picture, the swing-back must be pushed out at the bottom, until the screen or plate is *parallel* to the object; and this, as is obvious from the preceding remarks, is in the contrary direction to that required for the best definition. Hence, a tilt and a swing, tax the lens to its utmost, and always necessitate the use of a very small stop.

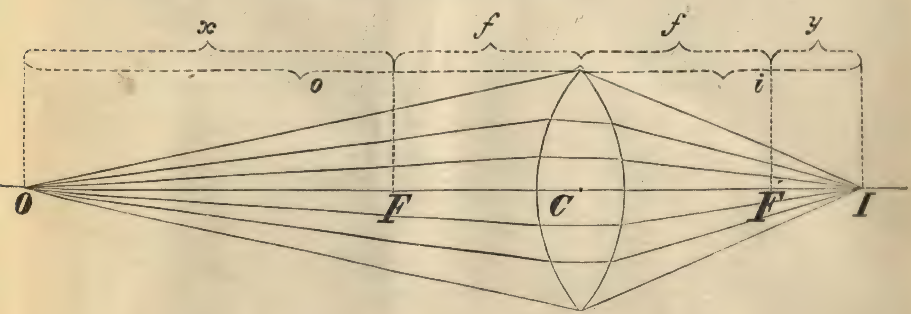
For portraiture also, as when taking a *standing* figure, the swing-back had better not be used. This operation resembles the case of copying where the lens performs at its best when kept on a level, facing the centre of the object, when a mean focus, as it were, is drawn between the centre and the extremities of the figure; this is the actual *modus operandi* pursued by some artists for taking their standing figures. Another plan, also dispensing with the swing-back, is to place the lens somewhat higher, viz., on a level with the chest, then to raise the camera front from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch. Then, to get the image equi-distant from the top and bottom of the screen involves a slight dip or inclination of the camera towards the object. This favours definition of the extremities of the figure, and the resulting picture approximates to the *natural* view of the face. I am disposed to recommend the latter plan as, in my opinion, it yields the best results.

ON CONJUGATE FOCI.

A simple and accurate rule has been given in the Appendix (page 19), whereby the relative positions of the planes of object and focussing screen—both measured from the optical centre of the lens—may be found for given enlargements or reductions.

The following short summary of the principles involved, and the accompanying table, are added to enable the photographer to obtain, at a glance, his necessary measurements.

We have only to deal with converging lenses.



Let $C\,F$ (or $C\,F_{\prime}$) the *equivalent* focus—or focus for parallel rays—of any lens be represented by f; the distance of the object O from the optical centre of the lens by o; and the distance of its conjugate I by i.

$$i = \frac{f\,o}{o-f} \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (1)$$

The relation between the conjugate points I and O are more clearly defined when referred to the focal points F and F'.

Let x be the distance of the object O from the focus F on the same side, and,

Similarly, let y be the distance of the image I from the focus F'.

Then $o = x + f \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (2)$

$$i = y + f \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (3)$$

Substituting these values in equation (1) we obtain

$$x\,y = f^2 \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad (4)$$

From this short equation, the positions of the conjugate points are very simply expressed.

The equivalent focus, or focus for parallel rays of any lens is the mean proportion between the distances made up by the differences of the two conjugate points from the corresponding focal points.

From equation (4) the distances x or y are known if either be expressed as a multiple of f.

For if $x = nf$	...	necessarily	$y = \frac{1}{n} f$
,, $x = 1000 f$	...	,,	$y = \frac{1}{1000} f$
,, $x = 10 f$	...	,,	$y = \frac{1}{10} f$
,, $x = 5 f$	...	,,	$y = \frac{1}{5} f$
,, $x = 2 f$	...	,,	$y = \frac{1}{2} f$ (see fig.)
,, $x = f$	...	,,	$y = f$

From this it is easily understood that the greater the distance of any object O from F, the less proportionately become the differences of distance between I and F. This explains why tables can be calculated giving distances from lenses, *beyond* which any object is in focus, for in these cases large differences in the value of x only produce very small ones in the value of y. (See p. 25.)

Again, the same equation (4) will shew the proportional sizes between image and object, for it is known that they are, as the distances o and i, from the optical centre of the lens.

$$\text{Let } R = \frac{i}{o}$$

By substituting the values of i and o from equations (2) and (3)

$$R = \frac{f + y}{f + x}$$

$$\text{By (4) } y = \frac{f^2}{x}$$

$$\text{Then } \frac{f + \frac{f^2}{x}}{f + x} = \frac{f}{x}$$

If x be given, as before, as a multiple of f,

$$R = \frac{f}{nf} = \frac{1}{n}$$

Thus, if the object be n times the focus of the lens from F, the image is $\frac{1}{n}$ the size of the object.

If the distance of the object from F be

$1000\,f$, $10\,f$, $5\,f$, &c., the image is
$\frac{1}{1000}\,f$, $\frac{1}{10}\,f$, $\frac{1}{5}\,f$, &c., the size of the object.

Thus the relative distances or relative sizes of object and image can be ascertained with any lens, and the rule deduced is as follows :—

For a given reduction with any lens, *the distance of the object from lens*, IS THE NUMBER OF TIMES PLUS ONE, MULTIPLIED BY THE FOCAL LENGTH OF THE LENS ;—and *the distance of screen from Lens* IS THE RECIPROCAL OF THE NUMBER OF TIMES, PLUS ONE, MULTIPLIED BY THE FOCAL LENGTH OF THE LENS, and *vice versâ* for a given enlargement.

To reduce an object four times with a lens of 6 inches focal length :—

Number of times.			Focus o Lens.	
4	+ 1 = 5,	multiplied by	6	= 30,

or distance of object from lens.

Reciprocal of number of times.			Focus of Lens.	
$\frac{1}{4}$	+ 1 = $1\frac{1}{4}$,	multiplied by	6	= $7\frac{1}{2}$,

or distance of screen from lens.

For a similar enlargement the above-named distances are reversed. (Compare with table.)

N.B.—The measurements in all cases are to be made from the *optical centre* of the lens ; or in the case of the Rapid Rectilinear Lenses from the diaphragm slot.

TO ENLARGE OR REDUCE.

e.g. Rapid Recti-linears.	Focus of Lens in inches	Number of Times.									
		Same Size.	2	3	4	5	6	7	8	9	10
		inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
$4\frac{1}{4} \times 3\frac{1}{4}$	4	8	6	$5\frac{1}{3}$	5	$4\frac{4}{5}$	$4\frac{2}{3}$	$4\frac{4}{7}$	$4\frac{1}{2}$	$4\frac{4}{9}$	$4\frac{2}{5}$
		8	12	16	20	24	28	32	36	40	44
5×4	6	12	9	8	$7\frac{1}{2}$	$7\frac{1}{5}$	7	$6\frac{6}{7}$	$6\frac{3}{4}$	$6\frac{2}{3}$	$6\frac{3}{5}$
		12	18	24	30	36	42	48	54	60	66
6×5	$8\frac{1}{4}$	17	$12\frac{3}{8}$	11	$10\frac{5}{16}$	$9\frac{9}{10}$	$9\frac{5}{8}$	$9\frac{3}{7}$	$9\frac{9}{32}$	$9\frac{1}{6}$	$9\frac{3}{40}$
		17	$24\frac{3}{4}$	33	$41\frac{1}{4}$	$49\frac{1}{2}$	$57\frac{3}{4}$	66	$74\frac{1}{4}$	$82\frac{1}{2}$	$90\frac{3}{4}$
$8\frac{1}{2} \times 6\frac{1}{2}$	11	22	$16\frac{1}{2}$	$14\frac{2}{3}$	$13\frac{3}{4}$	$13\frac{1}{5}$	$12\frac{5}{6}$	$12\frac{4}{7}$	$11\frac{3}{8}$	$12\frac{2}{9}$	$12\frac{1}{10}$
		22	33	44	55	66	77	88	99	110	121
10×8	13	26	$19\frac{1}{2}$	$17\frac{1}{3}$	$16\frac{1}{4}$	$15\frac{3}{5}$	$15\frac{1}{6}$	$14\frac{6}{7}$	$14\frac{5}{7}$	$14\frac{4}{9}$	$14\frac{3}{10}$
		26	39	52	65	78	91	104	117	130	143
12×10	16	32	24	$21\frac{1}{3}$	20	$19\frac{1}{5}$	$18\frac{2}{3}$	$18\frac{2}{7}$	18	$17\frac{7}{9}$	$17\frac{3}{5}$
		32	48	64	80	96	112	128	144	160	176
13×11	$17\frac{1}{2}$	35	$26\frac{1}{4}$	$23\frac{1}{3}$	$21\frac{7}{8}$	21	$20\frac{5}{12}$	20	$19\frac{11}{16}$	$19\frac{4}{9}$	$19\frac{1}{4}$
		35	$52\frac{1}{2}$	70	$87\frac{1}{2}$	105	$122\frac{1}{2}$	140	$157\frac{1}{2}$	175	$192\frac{1}{2}$
15×12	$19\frac{1}{2}$	39	$29\frac{1}{4}$	26	$24\frac{3}{8}$	$23\frac{2}{5}$	$22\frac{3}{4}$	$22\frac{2}{7}$	$21\frac{15}{16}$	$21\frac{2}{3}$	$21\frac{9}{20}$
		39	$58\frac{1}{2}$	78	$97\frac{1}{2}$	117	$136\frac{1}{2}$	156	$175\frac{1}{2}$	195	$214\frac{1}{2}$
18×16	24	48	36	32	30	$28\frac{4}{5}$	28	$27\frac{3}{7}$	27	$26\frac{2}{3}$	$26\frac{2}{5}$
		48	72	96	120	144	168	192	216	240	264
22×20	30	60	45	40	$37\frac{1}{2}$	36	35	$34\frac{2}{7}$	$33\frac{3}{4}$	$33\frac{1}{3}$	33
		60	90	120	150	180	210	240	270	300	330
25×21	33	66	$49\frac{1}{2}$	44	$41\frac{1}{4}$	$39\frac{3}{5}$	$38\frac{1}{2}$	$37\frac{5}{7}$	$37\frac{1}{8}$	$36\frac{2}{3}$	$36\frac{3}{10}$
		66	99	132	165	198	231	264	297	330	363

The above table is applied as follows :—

FOR ENLARGEMENT.—The focal length of the lens being known, find that number in the second *vertical* column of figures : pursue the line horizontally to the division of figures situated below the "number of times" division. The upper figure denotes the distance in inches between the object and lens, and the lower figure the distance of screen from lens.

FOR REDUCTION these two lines need only be reversed.

DIAMETER, INTENSITY RATIO, AND RELATIVE RAPIDITY OF EACH STOP OF THE SEVERAL VIEW LENSES.

Lens.	Stop.	Diameter.	Ratio.	Relative Rapidity.
No. 1 Quick-acting Stereo', focus $4\frac{1}{2}''$ ...	No. 10	·47	$\frac{1}{10}$	100
	x	·4	$\frac{1}{11}$	121
	2	·33	$\frac{1}{14}$	196
	3	·24	$\frac{1}{19}$	361
No. 2 Quick-acting Stereo', focus 6″ ...	No. 10	·62	$\frac{1}{10}$	100
	x	·53	$\frac{1}{11}$	121
	2	·43	$\frac{1}{14}$	196
	3	·3	$\frac{1}{20}$	400
5 × 4 Rapid Rectilinear, focus 6″	No. 0	·7	$\frac{1}{8\cdot5}$	72
	x	·612	$\frac{1}{10}$	100
	2	·53	$\frac{1}{11}$	121
	3	·38	$\frac{1}{16}$	256
	4	·27	$\frac{1}{22}$	484
	5	·18	$\frac{1}{33}$	1089
6 × 5 Rapid Rectilinear, focus $8\frac{1}{4}''$	No. 0	·9	$\frac{1}{9}$	81
	x	·775	$\frac{1}{11}$	121
	2	·67	$\frac{1}{12}$	144
	3	·475	$\frac{1}{17}$	289
	4	·34	$\frac{1}{24}$	576
	5	·24	$\frac{1}{34}$	1156
$8\frac{1}{2} \times 6\frac{1}{2}$ Rapid Rectilinear, focus 11″ ...	No. 0	1·25	$\frac{1}{9}$	81
	x	1·	$\frac{1}{11}$	121
	2	·85	$\frac{1}{13}$	169
	3	·625	$\frac{1}{17}$	289
	4	·44	$\frac{1}{25}$	625
	5	·31	$\frac{1}{35}$	1225
10 × 8 Rapid Rectilinear, focus 13″... ...	No. 0	1·6	$\frac{1}{8}$	64
	x	1·31	$\frac{1}{10}$	100
	2	1·125	$\frac{1}{12}$	144
	3	·8	$\frac{1}{16}$	256
	4	·56	$\frac{1}{24}$	576
	5	·4	$\frac{1}{33}$	1089
12 × 10 Rapid Rectilinear, focus 16″ ...	No. 0	1·7	$\frac{1}{8}$	64
	x	1·4	$\frac{1}{11}$	121
	2	1·2	$\frac{1}{13}$	169
	3	·85	$\frac{1}{19}$	361
	4	·6	$\frac{1}{26}$	676
	5	·4	$\frac{1}{40}$	1600

Lens.	Stop.	Diameter.	Ratio.	Relative Rapidity.
13 × 11 Rapid Rectilinear, focus 17½″ ...	No. 0	1·9	$\frac{1}{9}$	81
	x	1·63	$\frac{1}{11}$	121
	2	1·4	$\frac{1}{13}$	169
	3	1·	$\frac{1}{18}$	324
	4	·71	$\frac{1}{25}$	625
	5	·5	$\frac{1}{35}$	1225
	6	·35	$\frac{1}{50}$	2500
15 × 12 Rapid Rectilinear, focus 19½″ ...	No. 0	2·3	$\frac{1}{8·5}$	72
	x	1·85	$\frac{1}{11}$	121
	2	1·5	$\frac{1}{13}$	169
	3	1·15	$\frac{1}{17}$	289
	4	·8	$\frac{1}{24}$	576
	5	·55	$\frac{1}{35}$	1225
18 × 16 Rapid Rectilinear, focus 24″ ...	No. 0	2·8	$\frac{1}{8·5}$	72
	x	2·3	$\frac{1}{10}$	100
	2	1·9	$\frac{1}{13}$	169
	3	1·4	$\frac{1}{17}$	289
	4	1·	$\frac{1}{24}$	576
	5	·7	$\frac{1}{35}$	1225
22 × 20 Rapid Rectilinear, focus 30″ ...	No. 0	3·6	$\frac{1}{3·5}$	72
	x	2·94	$\frac{1}{10}$	100
	2	2·54	$\frac{1}{12}$	144
	3	1·8	$\frac{1}{17}$	289
	4	1·25	$\frac{1}{24}$	576
	5	·9	$\frac{1}{33}$	1089
	6	.65	$\frac{1}{46}$	2116
25 × 21 Rapid Rectilinear, focus 33″ ...	No. 0	3·6	$\frac{1}{9}$	81
	x	3·1	$\frac{1}{10}$	100
	2	2·68	$\frac{1}{12}$	144
	3	1·9	$\frac{1}{17}$	289
	4	1·34	$\frac{1}{24}$	576
	5	·95	$\frac{1}{35}$	1225
	6	·67	$\frac{1}{50}$	2500
2″ Rectilinear, focus 2¼″	No. 12	·18	$\frac{1}{12}$	144
	x	·155	$\frac{1}{15}$	225
	2	·127	$\frac{1}{18}$	324
	3	·09	$\frac{1}{25}$	625
	4	·064	$\frac{1}{35}$	1225
	5	·045	$\frac{1}{50}$	2500
Rectilinear Stereo', focus 3″	No. 10	·28	$\frac{1}{10}$	100
	x	·24	$\frac{1}{12}$	144
	2	·2	$\frac{1}{15}$	225
	3	·14	$\frac{1}{21}$	441
	4	·1	$\frac{1}{30}$	900

Lens.	Stop.	Diameter.	Ratio.	Relative Rapidity.
No. 1*aa* Wide-angle Rectilinear, focus 4″	No. 15	·295	1/13	169
	x	·24	1/17	289
	2	·205	1/20	400
	3	·145	1/27	729
	4	·1	1/40	1600
No. 1*a* Wide-angle Rectilinear, focus 5¼″...	No. 15	·35	1/15	225
	2	·245	1/21	441
	3	·175	1/30	900
	x	·151	1/35	1225
	4	·115	1/46	2116
No. 1 Wide-angle Rectilinear, focus 7″...	No. 15	·46	1/15	225
	2	·325	1/21	441
	3	·23	1/30	900
	x	·199	1/35	1225
	4	·16	1/44	1936
No. 2 Wide-angle Rectilinear, focus 8½″...	No. 15	·58	1/15	225
	x	·49	1/17	289
	2	·402	1/21	441
	3	·285	1/30	900
	4	·2	1/42	1764
No. 3 Wide-angle Rectilinear, focus 13″...	No. 15	·75	1/17	289
	x	·63	1/20	400
	2	·52	1/25	625
	3	·375	1/35	1225
	4	·26	1/50	2500
No. 4 Wide-angle Rectilinear, focus 15½″	No. 15	·9	1/17	289
	2	·7	1/24	576
	3	·5	1/30	900
	4	·35	1/44	1936
No. 5 Wide-angle Rectilinear, focus 16½″	No. 15	1·1	1/15	225
	2	·77	1/21	441
	3	·55	1/30	900
	4	·38	1/43	1849
	5	·27	1/60	3600
No. 1*a* Wide-angle Landscape, focus 5¼″...	No. 13	·398	1/13	169
	x	·34	1/15	225
	2	·281	1/18	324
	3	·24	1/22	484
	x	·15	1/35	1225
No. 1 Wide-angle Landscape, focus 7″ ...	No. 15	·46	1/15	225
	2	·325	1/21	441
	x	·282	1/25	625
	3	·23	1/30	900
	x	·199	1/35	1225

Lens.	Stop	Diameter.	Ratio.	Relative Rapidity
No. 2 Wide-angle Landscape, focus $8\frac{1}{2}''$...	No. 15	·566	$\frac{1}{15}$	225
	2	·4	$\frac{1}{20}$	400
	x	·346	$\frac{1}{24}$	576
	3	·283	$\frac{1}{30}$	900
	x	·24	$\frac{1}{35}$	1225
No. 3 Wide-angle Landscape, focus 10″	No. 15	·66	$\frac{1}{15}$	225
	2	·46	$\frac{1}{22}$	484
	x	·404	$\frac{1}{25}$	625
	3	·33	$\frac{1}{30}$	900
	x	·285	$\frac{1}{35}$	1225
No. 4 Wide-angle Landscape, focus 12″...	No. 15	·8	$\frac{1}{15}$	225
	2	·565	$\frac{1}{21}$	441
	x	·5	$\frac{1}{24}$	576
	3	·4	$\frac{1}{30}$	900
	x	·346	$\frac{1}{35}$	1225
No. 5 Wide-angle Landscape, focus 15″...	No. 20	·75	$\frac{1}{20}$	400
	x	·65	$\frac{1}{23}$	529
	2	·53	$\frac{1}{30}$	900
	3	·375	$\frac{1}{40}$	1600
No. 6 Wide-angle Landscape, focus 18″...	No. 20	·9	$\frac{1}{20}$	400
	x	·78	$\frac{1}{24}$	576
	2	·635	$\frac{1}{28}$	784
	3	·45	$\frac{1}{40}$	1600
	x	·375	$\frac{1}{48}$	2304
No. 7 Wide-angle Landscape, focus 22″...	No. 20	1·1	$\frac{1}{20}$	400
	x	·9	$\frac{1}{24}$	576
	2	·77	$\frac{1}{28}$	784
	3	·5	$\frac{1}{44}$	1936
No. 8 Wide-angle Landscape, focus 25″...	No. 20	1·25	$\frac{1}{20}$	400
	x	1·05	$\frac{1}{24}$	576
	2	·85	$\frac{1}{30}$	900
	3	·61	$\frac{1}{41}$	1681
	x	·5	$\frac{1}{50}$	2500
Patent Stereographic, focus 5″...	Stop 0	1·17	$\frac{1}{4}$	16
	x	1·00	$\frac{1}{5}$	25
	2	·825	$\frac{1}{6}$	36
	x2	·71	$\frac{1}{7}$	49
	3	·58	$\frac{1}{8}$	64
	4	·41	$\frac{1}{12}$	144
	5	·28	$\frac{1}{18}$	324

NOTE.—The apertures of all the stops supplied with my lenses (portrait and view) are so arranged that, counting from the *largest* to the next size *smaller*, the duration of exposure is about doubled Stops marked x are exception to this rule, and require an exposure only about *half as long again* as the *preceding larger* stop.

LENSES FITTING SAME SIZE FLANGE.

1—$3\frac{1}{4} \times 3\frac{1}{4}$, 5×4 and 6×5 Rapid Rectilinear. 2″ Rectilinear and 1*aa* Wide Angle Rectilinear. Rectilinear Stereo'.

2—$8\frac{1}{2} \times 6\frac{1}{2}$ Rapid Rectilinear. Nos. 1 & 2 quick acting Stereo'. New Stereo'. Patent Stereo'. Miniature. No. 1 Triple Achromatic. Nos. 1 & 1*a* Wide Angle Landscape. Nos. 1 & 1*a*, Wide Angle Rectilinear.

3—No. 1 Lantern.

4—1 B, 1 B long. 10×8 & 12×10 Rapid Rectilinear. No. 2 Lantern. No. 2 Wide Angle Rectilinear. Nos. 2 & 3 Wide Angle Landscape. No. 2 Triple Achromatic.

5—13×11 Rapid Rectilinear. 3 *D*. No. 3 Triple Achromatic.

6—15×12 Rapid Rectilinear. 2 *B*, 2 *B* patent. 1 *A* patent. 2 *C*. Nos. 4, 5, & 5*a* Wide Angle Landscape. No. 3 Wide Angle Rectilinear.

7—4 *D*. No. 4 Triple Achromatic.

8—18×16 Rapid Rectilinear. 5 *D*. No. 4 Wide Angle Rectilinear. No. 5 Triple Achromatic. No. 6 Wide Angle Landscape.

9—3 *B*. 3 *C*. 2 *A*. No. 5 Wide Angle Rectilinear.

10—22×20 & 25×21 Rapid Rectilinear. 6 *D*. 3 *A*. No. 6 Triple Achromatic. Nos. 7 & 8 Wide Angle Landscape.

11—4 *A* & 4 *B*.

12—30×24 Rapid Rectilinear. 5 *A*. 7 *D*.

13—Nos. 7 & 8 Triple Achromatic.

14—34×34 Rapid Rectilinear. 36×36 Triple Achromatic. 6 *A*. 8 *D*.

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